ELT-251: Device- and System-Level Thermal Packaging for Electric-Drive Technologies

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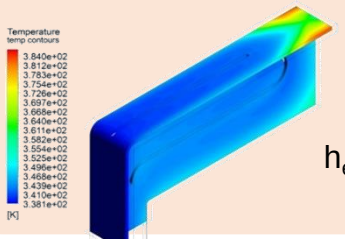
Relevance: • High performance power inverter thermal management • Rapid, precise multiphysics modeling of electric motors • Advanced, high performance bonding methods
Approach: • Single and boiling dielectric near junction cooling • Motor-CAD modeling of direct cooling strategies • Transient liquid phase bonding with validated diffusion model
Collaboration: • NREL • ORNL

ELECTROTHERMAL OUTER ROTOR MOTOR MODELLING

Heat Exchanger CFD Analysis

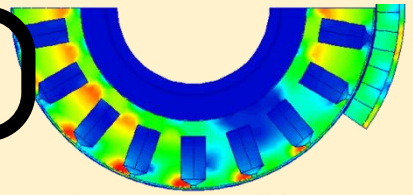


h_{eff} = 4538 W/m^{2}K

Motor-CAD Thermal Model

Motor-CAD E-Magnetic Model

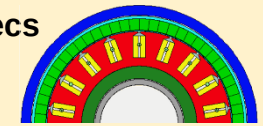
E-Magnetic Model Results



Peak torque condition:
- Average torque = 166.3 Nm, 1.2% torque ripple
- System efficiency = 96.4%
- Power factor = 0.79

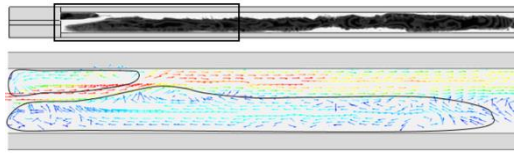
Known electromagnetic (EM)/motor specs

- Motor modelled with ANSYS Motor-CAD
- Simulation calculates EM results

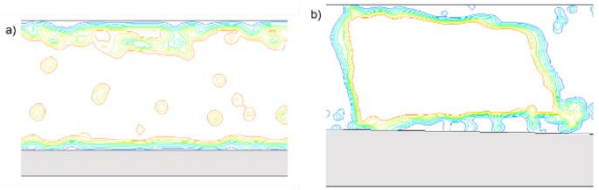


Custom t-shape for end-winding

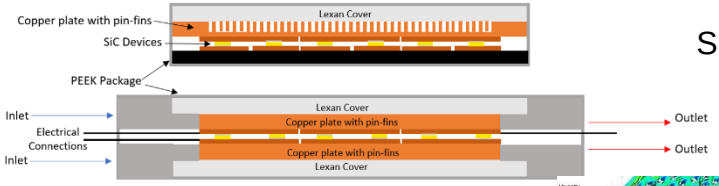
DEVICE-LEVEL TWO-PHASE THERMAL MANAGEMENT



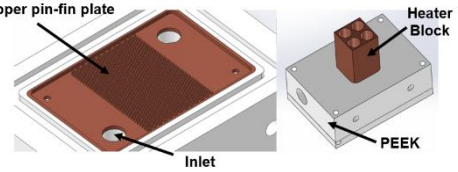
Shown: Asymmetric recirculation zones from inlet restriction



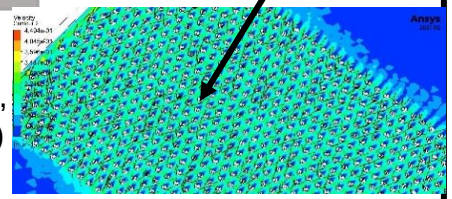
Shown: Cross section of vapor bubbles in straight and angled microchannels



Shown: Single, double-sided cooling structures designed for dielectric fluid, testing package for 1 kW/cm^2 (below)

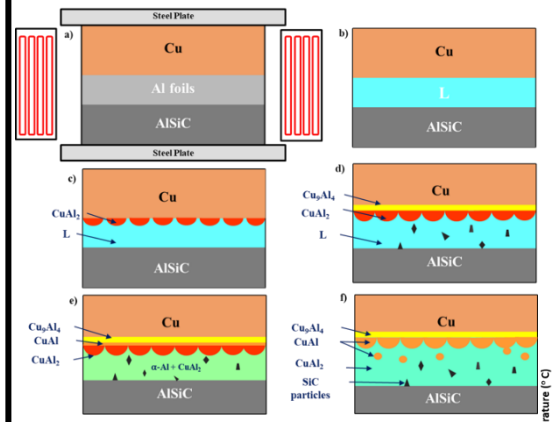


Simulation indicates thermal resistance of **26 mm^{2}K/W**

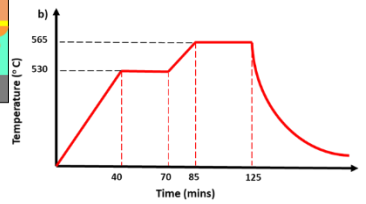


Shown: Velocity contours at device heat flux 750 W/cm^2 0.75 lpm flowrate

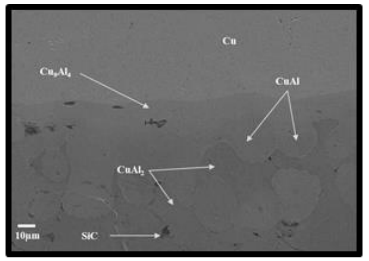
ADVANCED BONDING TECHNIQUES

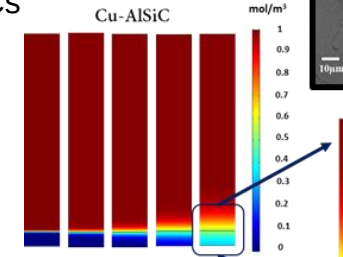


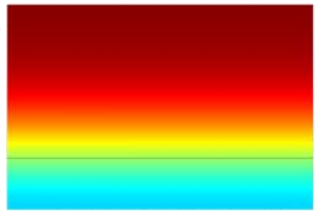
Shown: Evolution of interdiffusion and intermetallic (IMC) compound formation between Cu / AlSiC heated at 565°C (left), process temperature (below)



Shown: Modeling results of Cu / Al binary system at 565°C over 40 min bond time, Magnified scanning electron microscope (SEM) image of Cu/Al IMCs







Future work: • Ultra high heat flux dielectric two phase cooling • Experimental validation of direct winding cooling model • Electrical performance reliability quantification